A Resource-Sensitive Semantics for Equi and Raising

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Lexical Functional Grammar (LFG) analyses of equi and raising involve functional control equations, which structure-share the values of grammatical functions, making them token-identical at the level of f(unctional)-structure. Glue semantics for LFG works from f-structure and is resource-sensitive. This seems at first to be incompatible with structure-sharing. It is demonstrated that this is not so. By using LFG's parallel projection architecture, the Glue analysis of equi proposed here treats the clausal equi complement as denoting a property, which has been argued for on independent grounds by Chierchia (1984). It is also shown that the same approach can provide an analysis of raising in which clausal complements of raising verbs denote propositions, as required. The analysis also explains the ability of raising verbs to take expletive subjects and the inability of equi verbs to do so.

1 Introduction

Glue semantics provides a compositional, resource-sensitive semantics for natural language interpretation that is expressed using linear logic (Girard, 1987). It typically uses Lexical Functional Grammar (LFG; Kaplan and Bresnan 1982; Bresnan 2000) as its syntactic underpinning (Dalrymple, 1999). In this approach, lexical entries contain linear-logic meaning constructors that specify how they contribute to the meanings of larger syntactic constituents. The meanings of the larger constituents are derived using linear-logic deduction on the meanings of the parts. Thus, the semantics is compositional. Glue semantics is also resource-sensitive, because in a valid linear-logic deduction each premise is consumed as it is used and all premises must be consumed in reaching a conclusion.

This resource-sensitivity seems initially to be at odds with functional control in LFG f(unctional)-structures, which is expressed using functional identity equations, such as $(\uparrow \textsc{subj}) = (\uparrow \textsc{xcomp subj})$ (Bresnan, 2000). Functional control results in an f-structure which has

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two (or more) attributes with a token-identical value; we can say that the value is structure-shared between two attributes (Bresnan, 2000). This is often notationally expressed using a line connecting the two f-structures:

(1) $$f\begin{bmatrix} \textsc{a} & g[\ \ ] \\ \textsc{b} & \end{bmatrix}$$

In this f-structure $\langle f\ \textsc{a}\rangle = \langle f\ \textsc{b}\rangle$. Since $\langle f\ \textsc{a}\rangle = g$, we can say that g is structure-shared as the value of $\langle f\ \textsc{a}\rangle$ and $\langle f\ \textsc{b}\rangle$. Functional control has been instrumental in LFG analyses of various phenomena (Kaplan and Bresnan, 1982).

Two such phenomena are raising verbs and a subset of equi verbs (Kaplan and Bresnan, 1982),[1] as in the following sentences:

(2) Gonzo seemed to leave. RAISING

(3) Gonzo tried to leave. EQUI

In both cases, the matrix verb takes an IP complement in c(onstituent)-structure which is represented as an XCOMP in f-structure.[2]

The problem that equi presents for a resource-sensitive semantics is essentially the following. The matrix subject contributes a semantic resource. This semantic resource is then consumed in determining the semantics of the control verb *try*. Since the matrix subject and the controlled subject are *token-identical*, consuming the resource contributed by the matrix subject leaves no resource to consume in the interpretation of the controlled verb (*leave*). This problem does not arise with raising verbs. The raised argument is only consumed in the semantics of the raising verb's complement, as it is not a semantic argument of the raising verb. Thus, the resource-sensitivity is an issue in the analysis of equi only.

In this paper I will show that the conflict between resource-sensitivity and functional control that equi verbs exemplify can, contrary to initial appearances, be handled elegantly in Glue semantics. The analysis that I propose relies on LFG's projection architecture to give a parsimonious account of the equi and raising facts discussed, by allowing for mismatches between the various levels of representation, as is

[1] The term 'equi' comes from the 'Equivalent NP Deletion' transformation (Postal, 1972). These are also known as control verbs, but in the context of LFG this is confusing, as it is easy to mix up this use of the term control with the independent f-structure relation of function control. I will use the terms "equi" and "control" interchangeably, where there is no risk of confusion.

[2] In a related subcategorization, the raising verb selects for a CP/COMP, like the *that*-clause in *It seems that Gonzo left*. See section 6.2 for further discussion.

the norm in LFG. Thus, although both equi verbs like *try* and raising verbs like *seem* take IP complements in c-structure that map to XCOMPS at f-structure, the interpretation of the two types of verb differs at the level of s(emantic)-structure. In fact, the analysis that I propose treats the denotation of an equi verb's controlled complement as a property, which has been argued for on independent semantic grounds (Chierchia, 1984). By contrast, a raising verb's complement denotes a proposition. In addition, I will show that Glue semantics can give an account of raising in which the fact that the raising verb takes a proposition-denoting complement entails that the raised argument can play no role in the semantics of the raising verb, as a direct result of resource-sensitivity. Thus, the Glue semantics analysis correctly predicts that the clausal complement of an equi verb denotes a property, that the IP or CP complement of a raising verb denotes a proposition, and that the raised argument can be an expletive, while the controller cannot be one.

The structure of the paper is as follows. In section 2 I give an overview of the debate concerning the semantics of equi verbs. I accept Chierchia's argument that the denotation of the IP complement of an equi verb is a property. Then, in section 3, I outline the classic LFG analysis of equi and raising that I adopt (Kaplan and Bresnan, 1982; Zaenen and Engdahl, 1994). This is followed by a brief overview and discussion of Glue semantics, linear logic and resource-sensitivity, and the projection architecture of LFG (section 4). In section 5 I discuss the apparent problem between resource-sensitivity and structure-sharing. Finally, in section 6, I bring all these strands together and give a Glue analysis of equi and raising that has the desirable features discussed above.

2 Two Theories of the Semantics of Equi

There are two well-established approaches to the semantics of equi verbs. The difference between the two approaches has to do with the denotation of the controlled IP complement of the equi verb. The first approach argues that the controlled complement denotes a proposition (Pollard and Sag, 1991, 1994), while the second approach argues that it denotes a property (Chierchia, 1984, 1985; Chierchia and Jacobson, 1986; Dowty, 1985; Montague, 1974). I will therefore call these the *propositional* and *property* theories of control respectively.

According to the propositional theory of control, the sentence in (4a) would have the translation given in (4b). The subject equi verb *try* is then a function from a proposition to a 1-place predicate, as in

(4c). (5) provides an example of an object equi verb.

(4) a. Gonzo tried to leave.

b. *try*(*Gonzo*, *leave*(*Gonzo*)))

c. try: ⟨⟨s, t⟩, ⟨e, t⟩⟩

(5) a. Gonzo persuaded Andrew to order a pizza.

b. *persuade*(*Gonzo*, *Andrew*, *order*(*Andrew*, *pizza*)))

c. persuade: ⟨⟨s, t⟩, ⟨e, ⟨e, t⟩⟩⟩

The propositional stance is a long-standing view in generative grammar (Rosenbaum, 1967) and is a natural consequence of any syntactic theory that proposes that *leave* in (4a) subcategorizes for a subject at some syntactic level of representation (essentially for reasons of argument structure representation). This includes most well-known recent theories, such as Government and Binding Theory (Chomsky, 1986), the Minimalist Program (Chomsky, 1995), HPSG (Pollard and Sag, 1994), and LFG.[3] Assuming the presence of a subject in the syntax and assuming that there is some direct correspondence between syntax and semantics, the denotation of the controlled complement must be a proposition, as there are no free arguments in the semantics.

The property theory, on the other hand, analyzes the controlled complement as denoting a property. Again, this is illustrated for the subject control verb *try* and the object control verb *persuade*.

(6) a. Gonzo tried to leave.

b. *try(Gonzo, λx.leave(x))*

c. try: ⟨⟨s, ⟨e, t⟩⟩, ⟨e, t⟩⟩

(7) a. Gonzo persuaded Andrew to order a pizza.

b. *persuade(Gonzo, Andrew, λx.order(x, pizza))*

c. persuade: ⟨⟨s, ⟨e, t⟩⟩, ⟨e, ⟨e, t⟩⟩⟩

According to typical formulations of the property theory, there is no level of representation in the syntax or semantics where the controlled complement has a subject. The relevant argument of the equi verb acts as the 'understood subject' merely due to lexical entailments associated with the equi verb (Jacobson, 1990).

Chierchia (1984) argues that the propositional theory of control yields false inference patterns as in (8).

[3]The most notable exception is Categorial Grammar (Jacobson, 1990; Carpenter, 1997), with which Glue semantics has some affinities.

Chierchia's analysis seems right to me.

(8) **Propositional inference pattern**:

```
try(Gonzo, leave(Gonzo))
∀P.[try(Gonzo, P) → try(Andrew, P)]
-----------------------------------
try(Andrew, leave(Gonzo))
```

```
Gonzo tried to leave.
Andrew tried everything that Gonzo tried.
-----------------------------------
??
[* Andrew tried for Gonzo to leave.]
```

Here P is a variable over propositions. Since the second argument of *try* denotes a proposition, by hypothesis, the conclusion can only be that there is a relation of trying between the individual *Andrew* and the proposition *leave(Gonzo)*. But this is nonsensical, and there is no English sentence that means this. The closest approximation is not grammatical.

On the other hand, the property theory yields the correct inference pattern.

(9) **Property inference pattern**:

```
try(Gonzo, λx.leave(x))
∀P.[try(Gonzo, P) → try(Andrew, P)]
-----------------------------------
try(Andrew, λx.leave(x))
```

```
Gonzo tried to leave.
Andrew tried everything that Gonzo tried.
-----------------------------------
Andrew tried to leave.
```

Here P is a variable over properties, and both the individuals *Andrew* and *Gonzo* are related to this property by the relation of trying. Thus, the property denotation correctly captures the inference that if Andrew tried everything that Gonzo tried and Gonzo tried to leave, then Andrew tried to leave, too.

Pollard and Sag (1991, 1994) mention another fact that is relevant to choosing between the propositional and property theories of control. It has to do with what Chierchia (1990) calls "attitudes *de se*", following Lewis (1979). Consider the following argument schema:

(10) Ben Affleck$_i$ believes he$_i$ is sexy.
Matt Damon believes everything that Ben Affleck believes.

Matt Damon$_j$ believes that he$_j$ is sexy.

This involves an attitude *de se* because Ben Affleck has a belief about himself and Matt Damon putatively has the same belief about himself.

The basic argument is as follows: here we have a verb, *believe*, that clearly takes a propositional argument, yet we have essentially the same kind of inference pattern as in the cases that Chierchia discussed (see (9) above). So, this kind of inference has to be dealt with for propositions in general and the solution to this problem could rescue the propositional theory of control, as it could be extended to account for inferences like (9) (Pollard and Sag, 1994:282–283).

There are at least three problems with this. First, the promised solution has not actually been given, so it is hard to evaluate the claim that it can rescue the propositional theory of control. Thus, attitudes *de se* may or may not be arguments against the property theory of control, but they are definitely not directly arguments *for* the propositional theory. Second, speakers vary as to whether they get the inference in (10). However, the same variation is absent in the inference in (9). Thus, according equal status to the two inferences does not account for native speaker intuitions. Third, it is only if the first line of the argument in (10) has a bound variable reading that the inference follows. But, the bound variable depends on a position outside the one quantified over ("everything that Ben Affleck believes"), so it is far from clear how the variable binding holds in the second line, which is necessary to establish the conclusion. In other words, it may or not be true that Matt Damon believes what is in the conclusion, but this would only follow in *this* argument if Ben Affleck believes Matt Damon is sexy and that premise is missing.

A reviewer has pointed out another difference between (9) and (10) that also concerns the bound variable reading. Insofar as there is such a reading available for (10), it is mediated by an overt, nonreflexive pronoun. Such pronouns can give rise to strict/sloppy contrasts in the interpretation of ellipsis (Lappin, 1996; Sag, 1976; Schieber et al., 1996). Thus, the inference in (10) might be explained by appealing to a sloppy interpretation of *he*. But, equi verbs do not allow sloppy interpretations: *Gonzo tried to leave, and Andrew did too* can only have a strict reading in the ellipsis. In fact, this provides another kind of inference pattern that the property theory explains and that the propositional theory gets wrong (Asudeh, 2000:7–8). The property theory explains the absence of this reading, because there is no variable corresponding to the embedded subject to reconstruct in the ellipsis. So the difference between (9) and (10) may ultimately have to do with the correct theory of ellipsis, and as such (10) does not necessarily present an obstacle for the property theory, which already gets some of the ellipsis facts right.[4]

[4] A related problem to (10) has been raised by Zec (1987), who notes that Serbo-Croatian (Zec's term) sentences like the following pose a problem for the property

3 Equi and Raising as Functional Control

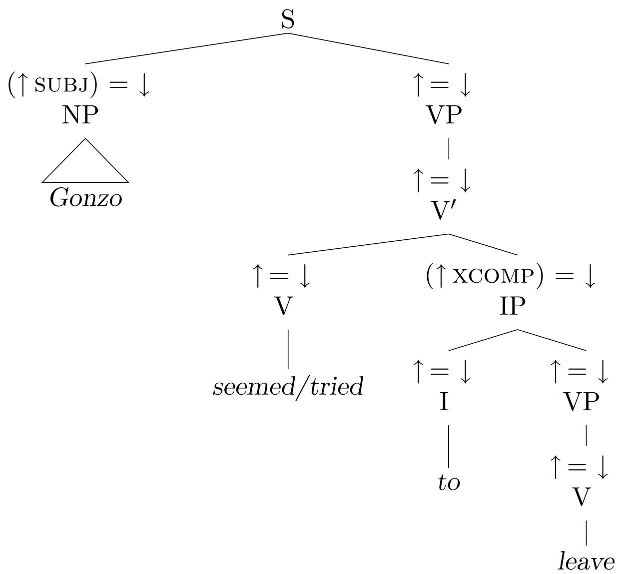
In this section I will present LFG analyses of raising verbs and the subclass of equi verbs I am concerned with, namely those that involve functional control. For purposes of illustration, I will use sentences (2) and (3) from section 1, which are repeated here for convenience:

(2) Gonzo seemed to leave.

(3) Gonzo tried to leave.

The c-structures for these two sentences are identical (save for the terminal nodes):

(12)



In either case, the matrix verb takes an IP complement that serves as its f-structure XCOMP.

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theory of control (Zec, 1987:142).

(11) Petar je pokušao da dodje
Petar Aux tried Comp come(Pres)
'Peter tried to come.'

Zec argues that the complement to this equi verb is a CP with a null pronominal subject, which is anaphorically controlled by (i.e. coindexed with) the matrix verb's subject at f-structure. Yet, the same inferences that Chierchia uses to argue for the property denotation of the clausal complement hold in Serbo-Croatian. In related work (Asudeh, 2000), I exploit LFG's parallel projection architecture to deal with this issue and with other objections to the property theory which have to do with the binding of reflexives in the clausal complement (Pollard and Sag, 1994:283).

The differences between a subject raising verb, like *seem*, and a subject equi verb, like *try*, are semantic in nature and are represented in the f-structure description equations in their lexical entries and in their semantics. I will return to difference in the semantics in section 6 below. Leaving that aside, the lexical entries for *seem* and *try* would be as follows:

(13) seem V $(\uparrow \textsc{pred}) = \text{`seem}\langle(\uparrow \textsc{xcomp})\rangle(\uparrow \textsc{subj})\text{'}$
$(\uparrow \textsc{xcomp subj}) = (\uparrow \textsc{subj})$

(14) try V $(\uparrow \textsc{pred}) = \text{`try}\langle(\uparrow \textsc{subj}), (\uparrow \textsc{xcomp})\rangle\text{'}$
$(\uparrow \textsc{xcomp subj}) = (\uparrow \textsc{subj})$

The only difference between the lexical entries, aside from the name of the PRED relation, is that the equi verb *try* selects for a thematic subject, while the raising verb *seem* does not. This difference is represented by having the thematic subject inside the angled brackets of the PRED, while the nonthematic subject is outside these brackets.

This difference in argument structure possibilities is reflected in the fact that raising verbs allow the raised argument to be replaced by an expletive or idiom chunk, while equi verbs do not allow such replacement of the equi controller (Bresnan, 1982a):[5]

(15) a. It seemed to rain.
b. *It tried to rain.

a. Tabs seemed to be kept on Gonzo.
b. *Tabs tried to be kept on Gonzo.

In LFG-theoretic terms, a nonthematic subject can be realized with no PRED of its own, whereas a thematic subject must have a PRED (Kaplan and Bresnan, 1982; Zaenen and Engdahl, 1994).

Despite this difference, in both cases there is a functional control equation, $(\uparrow \textsc{xcomp subj}) = (\uparrow \textsc{subj})$, that identifies the matrix subject with the subject of the complement. This results in the following f-structures for (2) and (3).

(16)
$$\begin{bmatrix} \textsc{pred} & \text{`seem}\langle(\uparrow \textsc{xcomp})\rangle(\uparrow \textsc{subj})\text{'} \\ \textsc{subj} & \begin{bmatrix} \textsc{pred} & \text{`Gonzo'} \end{bmatrix} \\ \textsc{xcomp} & \begin{bmatrix} \textsc{pred} & \text{`leave}\langle(\textsc{subj})\rangle\text{'} \\ \textsc{subj} & \end{bmatrix} \end{bmatrix}$$

[5] I am indebted to a reviewer, who reminded me of the idiom chunk test to distinguish raising and equi.

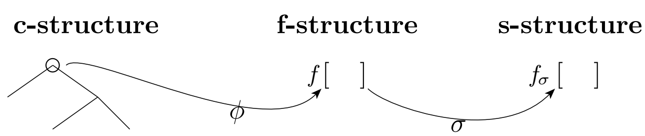
(17)
$$\begin{bmatrix} \textsc{pred} & \text{‘try}\langle(\uparrow \textsc{subj}), (\uparrow \textsc{xcomp})\rangle\text{’} \\ \textsc{subj} & \begin{bmatrix} \textsc{pred} & \text{‘Gonzo’} \end{bmatrix} \\ \textsc{xcomp} & \begin{bmatrix} \textsc{pred} & \text{‘leave}\langle(\textsc{subj})\rangle\text{’} \\ \textsc{subj} & \end{bmatrix} \end{bmatrix}$$

Thus, the only syntactic difference between an equi verb and a raising verb is that the former takes a thematic subject (i.e. nonexpletive subject), while the latter takes a nonthematic (i.e. raised or expletive subject).

4 Glue Semantics

Glue semantics is a theory of semantics that has been developed in recent LFG work (Dalrymple, 1999). LFG has a parallel projection architecture, which means that there are various levels of linguistic representation, called *projections*, present in *parallel*, and these projections are related by functional correspondences (also know as projection functions) which map elements of one projection onto elements of another (Kaplan, 1987, 1995). This is a generalization of the original notion of functional correspondence in which the ϕ-function maps c(onstituent)-structures onto f(unctional)-structures (Kaplan and Bresnan, 1982). As a result of this generalization, f-structures are mapped onto s(emantic)-structures by the σ-function (Dalrymple et al., 1999a). This results in an architecture like the following:

(18)



Although Glue semantics does not in any crucial way rely on an LFG grammatical architecture, in practice it has been taken to be a theory and formalization of LFG's semantics. In particular, Glue semantics is a theory of the syntax-semantics interface (the σ-function) and semantic representation and interpretation (s-structure).

The Glue semantics approach assumes two independent logics, one for meaning assembly and one for meaning representation and interpretation (Dalrymple, 1999). In other words, the meaning language that is used in Glue semantics is independent of the language used for representing semantic structures and performing operations on these structures (the Glue language). The Glue language is a fragment of linear logic (Girard, 1987), which is used to give a systematic, compositional semantics. The meanings of larger parts are derived from the meanings of smaller parts using linear-logic deduction. Semantic composition is based on 1) lexical contributions and 2) functional (f-structure) relations. Thus, Glue semantics is compositional in the Fregean sense: the meanings of constituents are made up of the meanings of their parts and their mode of combination. Glue semantics is not compositional in the stricter sense espoused in the Montague and Categorial Grammar traditions. In strictly compositional semantics, syntactic structures are interpreted at every node, whether the interpretation is rule-by-rule, as in traditional Montague Grammar (Montague, 1974), or type-driven, as in more recent strictly compositional theories of semantics (Klein and Sag, 1985; Heim and Kratzer, 1998).

It is precisely this notion of strict compositionality that is in some sense responsible for the debate about the denotation of clausal equi complements. It is only if one assumes a strict match between syntax and semantics that one has to assume that the presence of a subject in the syntax implies its presence in the semantics, which in turn implies the propositional denotation. Strictly compositional approaches maintain the property denotation at the expense of having no subject at any level of representation. But, not having a subject in any representation leads to various problems, and the solutions are not satisfactory. In particular, reflexive binding and quantifier scoping are complicated (Carpenter, 1997:347–354, 436–439).

The fact that Glue semantics relates structures to their meanings *systematically*, through the mediating linear-logic representation, but not strictly compositionally, is crucial. Glue semantics works off f-structure, which has the subjects required for reflexive binding and the interaction of scope with raising and equi (Asudeh, 2000). However, the f-structure is interpreted using the Glue language and not simply with a semantic function that yields its denotation. Thus, Glue employs LFG's parallel projection architecture to its advantage, allowing the various levels to correspond and vary systematically.

Let us look at a (simplified) lexical entry, for the proper name *Gonzo*:

(19) Gonzo NP $(\uparrow \textsc{pred}) = \text{‘Gonzo’}$
$(\uparrow \textsc{number}) = \textsc{sg}$
$(\uparrow \textsc{person}) = 3$
$\text{gonzo} : \uparrow_\sigma$

The meta-variable $\uparrow$ ranges over f-structure labels as per usual (Kaplan and Bresnan, 1982), and this lexical entry makes standard assertions about the category, predication feature, and agreement features of the word *Gonzo*. The last line provides the Glue *meaning constructor* for this word (Dalrymple et al., 1999a), which states the meaning of the σ-projection of *Gonzo*'s f-structure is the constant *gonzo*. The colon (:), is an uninterpeted binary predicate symbol, which relates a semantic structure such as $\uparrow_\sigma$, specified in Glue language (i.e. linear logic), to a meaning P, specified in the meaning language of choice (Dalrymple et al., 1999a). In this paper I assume a simple lambda-calculus as the meaning language, although the choice is in principle free.[6]

In more recent work on Glue semantics, the meaning language and Glue language have been related using the Curry-Howard isomorpism (Dalrymple et al., 1999b). This isomorphism relates two logics while at the same time demanding that operations in each do not constrain operations in the other. The advantage of using this isomorphism, is that higher order unification, which was previously used for variable substitution in the meaning language, can be replaced with simple function application and lambda abstraction. Furthermore, the isomorphism's separation of the two logics has the welcome result that proofs can only fail in the Glue language, and cannot fail simply due to failure in the meaning language. This further restricts our formalism and the analyses we can couch in it.

The present analysis and much other current work on Glue at Xerox PARC uses the implicational fragment of linear logic. This means that in a natural deduction proof system, implication introduction corresponds to lambda abstraction, and implication elimination corresponds to function application. The analysis presented here uses only implication elimination and the natural deduction proof rule for this is simply modus ponens:

(20) $$\frac{A \qquad A \multimap B}{B} \multimap_{\mathcal{E}}$$

The following proof of $a,\ a \multimap b \vdash b$ serves as a simple illustration.

(21) $$\frac{x : a \qquad P : a \multimap b}{P(x) : b}\, application : \multimap_{\mathcal{E}}$$

We start with our two premises, a and $a \multimap b$. We use the a to eliminate the implication and derive b. This corresponds to application of the meaning of b, the function P, to the meaning of a, the variable x. It

[6] For example, Dalrymple et al. (1999a) demonstrate the use of Discourse Representation Theory (Kamp and Reyle, 1993) as the meaning language, while most of the papers in Dalrymple (1999) use some variety of typed intensional logic as the meaning language.

should be noted that the application step makes implicit use of the lambda calculus η-equivalence, whereby $\lambda y.P(y) \equiv_\eta P$.

5 Resource-Sensitivity and Structure-Sharing

Part of the appeal of Glue semantics is the formalization of the Glue language using linear logic, which provides a well-understood set of proof rules for deduction. In addition, the proof theory for linear logic can be formulated both in the natural deduction and sequent calculus styles (Dalrymple et al., 1999a).

But the most appealing property of linear logic is that linear-logic deduction is *resource-sensitive*: each premise is consumed as it is used and all premises must be consumed in reaching a conclusion. This means, for example, that the logical equivalance known as duplication does not hold in Glue semantics. In other words $A \not\equiv (A \otimes A)$, as the righthand side of the equivalence introduces two resources that must *both* be consumed in a valid deduction, whereas the lefthand side introduces only one resource.

Resource-sensitivity is appealing because it directly captures the generalization that lexical items and phrases each contribute exactly once to the meaning of the constituent that they make up (Dalrymple et al., 1999a:15–16). In many theories of natural language semantics, this does not follow directly from the logic used, but is rather a tacit assumption.[7] As Klein and Sag (1985:172) write[8]

> [W]e do not want the set S [of semantic representations of a phrase] to contain *all* meaningful expressions of IL [Intensional Logic] which can be built up from the elements of S, but only those which use each element exactly once.

Thus, resource-sensitivity seems to be a deep generalization about natural language semantics, and this property is straightforwardly maintained in Glue semantics through the use of linear logic, which is by definition resource-sensitive.

However, it is precisely this resource-sensitivity that clashes with structure-sharing, as asserted through functional identity equations. Functional identity asserts that one argument is simultaneously the value of two paths in an f-structure. That is, the subject of the outer f-structure in (17) and that of the XCOMP are *token-identical*. So, in deriving a meaning for an equi sentence, if we consume the meaning

[7] Again, Categorial Grammar is a notable exception.

[8] Cited in Dalrymple et al. (1999a:15).

of the matrix subject, then we have also consumed the meaning of the controlled subject. Thus, functional identity and resource-sensitivity are at odds and, since functional identity is a well-established syntactic mechanism in LFG, the burden is on Glue semantics to accommodate the discrepancy.

6 A Glue Analysis of Equi and Raising

In this section, I propose a Glue analysis of equi which reconciles functional identity with resource-sensitivity (section 6.1). The analysis maintains a property denotation for the controlled complement in the semantics, thus accounting for Chierchia's observations. I also show how the same style of analysis gives a satisfactory semantics for raising (section 6.2).

6.1 Equi

The essential Glue semantics is now in place and we can proceed to do a derivation for sentence (3), which is repeated here for convenience:

(3) Gonzo tried to leave.

This sentence has the c-structure given above in (12). Together with the feature descriptions in the lexical entry for *try* in (14), this yields the f-structure (17), which is repeated here with f-structure labels:

(17)
$$f\left[\begin{array}{ll} \textsc{pred} & \text{`try}\langle(f\ \textsc{subj}),\ (f\ \textsc{xcomp})\rangle\text{'} \\ \textsc{subj} & g\left[\begin{array}{ll}\textsc{pred} & \text{`Gonzo'}\end{array}\right] \\ \textsc{xcomp} & h\left[\begin{array}{ll}\textsc{pred} & \text{`leave}\langle(\textsc{subj})\rangle\text{'} \\ \textsc{subj} & \end{array}\right]\end{array}\right]$$

Using the f-structure node labels in (17) to instantiate the $\uparrow$ arrows, we get the following Glue parts for the lexical entries for this sentence:[9]

[9] I have tacitly assumed in this analysis, as evident from the c-structure (12), that *to* is simply a co-head with the embedded verb, and it does not make a semantic contribution here (reflected by its lack of a PRED), much like an expletive argument of a raising verb. This analysis is a long-standing one in LFG (Kaplan and Bresnan, 1982; Bresnan, 2000). However, should one wish to treat *to* as a raising verb, the Glue semantics analysis presented here does not need to change. The sentence then simply is a case of a raising verb embedded under an equi verb, and I have shown elsewhere that this analysis can handle such examples in general (Asudeh, 2000). For simplicity's sake, I have adopted the older analysis here.

$$
\begin{array}{llll}
(22) & \text{gonzo}: & & \uparrow_\sigma \\
 & & = & g_\sigma \\
 & \lambda P \lambda y.\text{try}(y, P): & & ((\uparrow \text{XCOMP SUBJ})_\sigma \multimap (\uparrow \text{XCOMP})_\sigma) \\
 & & & \quad \multimap ((\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma) \\
 & & = & (g_\sigma \multimap h_\sigma) \multimap (g_\sigma \multimap f_\sigma) \\
 & \lambda x.\text{leave}(x): & & (\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma \\
 & & = & g_\sigma \multimap h_\sigma
\end{array}
$$

In this formulation, P is a variable of type $\langle$s, $\langle$e, t$\rangle\rangle$, the intension of a property. Thus, *try* is of type $\langle\langle$s, $\langle$e, t$\rangle\rangle$, $\langle$e, t$\rangle\rangle$, as discussed in section 2 above.

The Glue deduction is straightforward, and involves only two instances of linear implication elimination ($\multimap_{\mathcal{E}}$). I present it first without the meaning terms, for exposition:

(23)
$$
\dfrac{\dfrac{g_\sigma \multimap h_\sigma \qquad (g_\sigma \multimap h_\sigma) \multimap (g_\sigma \multimap f_\sigma)}{g_\sigma \multimap f_\sigma}\multimap_{\mathcal{E}} \qquad g_\sigma}{f_\sigma}\multimap_{\mathcal{E}}
$$

The proof with the meaning terms is given in Figure 1.1 on the facing page. Through the use of the Curry-Howard isomorphism, the two eliminations in the Glue correspond to function application in the meaning language. The resource for the structure-shared subject is contributed only once, by the matrix subject, and it is consumed in the righthand implication, by the matrix verb, *tried*, after it has consumed the resource for the entire embedded complement. The lefthand implication is a function from the meaning of the controlled subject, which is identical to its controller (the matrix subject), to the meaning of the controlled infinitival, but it never consumes its subject's resource. As a result, the meaning of the entire sentence headed by the control verb is a function from a property to a function from the an individual to a truth value. Thus, we have the property theory of control in our semantics: the meaning of the verb *try* is a relation between an individual (the matrix subject) and a property (the controlled infinitival). There is no semantic copy of the matrix subject in the infinitival's semantics: the controlled, infinitival subject is used solely in computing the property function for the infinitival. Thus, there is a successful proof of the Glue semantics of sentence (3), *Gonzo tried to leave*. Furthermore, the meaning of *try* is a relation between an individual and a property, just as argued for by Chierchia (1984).

$$\cfrac{\cfrac{\lambda x.\mathrm{leave}(x) : g_\sigma \multimap h_\sigma \qquad \lambda P \lambda y.\mathrm{try}(y, P) : (g_\sigma \multimap h_\sigma) \multimap (g_\sigma \multimap f_\sigma)}{\lambda y.\mathrm{try}(y,\ \lambda x.\mathrm{leave}(x)) : g_\sigma \multimap f_\sigma} \qquad \mathrm{gonzo} : g_\sigma}{\mathrm{try}(\mathrm{gonzo},\ \lambda x.\mathrm{leave}(x)) : f_\sigma}$$

Figure 1.1: The proof from (23), with the meaning terms added to it.

6.2 Raising

The analysis of raising is similar in its syntax, as we have already observed. However, the raised argument bears no semantic relation to the raising verb, and is only interpreted in the semantics of its propositional complement. For example, the raised subject of *seem* in sentence (2) is not the subject of *seem*, because *seem* is semantically a one-place predicate with a propositional argument:

(2) Gonzo seemed to leave.

This distinction between the semantic relationship of the raised argument to the raising verb and the semantic relationship of the controlled argument to the equi verb is reflected in the Glue semantics. Here is the Glue and corresponding meaning language term for a subject raising verb like *seem*.

(24) seem V $\lambda\mathcal{P}.\text{seem}(\mathcal{P}) : (\uparrow \text{XCOMP})_\sigma \multimap \uparrow_\sigma$

The variable $\mathcal{P}$ is over propositions and is of type $\langle$s, t$\rangle$. Thus, a subject raising verb is of type $\langle\langle$s, t$\rangle$, t$\rangle$, as expected. This is reflected in the Glue language by the fact that the subject raising verb only consumes its XCOMP's meaning to get its own meaning. It is the XCOMP itself that consumes its subject's meaning, even though its subject is also the subject of the raising verb by functional control, resulting in a Glue proof with a different structure.

Recall that the f-structure for (2) is (16), repeated here with f-structure labels.

(16)
$$f\left[\begin{array}{ll} \text{PRED} & \text{`seem}\langle(\uparrow \text{XCOMP})\rangle(\uparrow \text{SUBJ})\text{'} \\ \text{SUBJ} & g\left[\begin{array}{ll}\text{PRED} & \text{`Gonzo'}\end{array}\right] \\ \text{XCOMP} & h\left[\begin{array}{ll}\text{PRED} & \text{`leave}\langle(\text{SUBJ})\rangle\text{'} \\ \text{SUBJ} & \end{array}\right] \end{array}\right]$$

Again, using these f-structure labels to instantiate the variables in the f-descriptions, we get the following lexical entries for (2).

(25)
$$\begin{array}{rcl} \text{gonzo} : & & \uparrow_\sigma \\ & = & g_\sigma \\ \lambda\mathcal{P}.\text{seem}(\mathcal{P}) : & & (\uparrow \text{XCOMP})_\sigma \multimap \uparrow_\sigma \\ & = & h_\sigma \multimap f_\sigma \\ \lambda\text{x}.\text{leave}(\text{x}) : & & (\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma \\ & = & g_\sigma \multimap h_\sigma \end{array}$$

With these Glue premises, we can again construct a simple proof using only implication elimination in the linear logic and corresponding function application in the meaning language.

(26)
$$\dfrac{\dfrac{\text{gonzo} : g_\sigma \qquad \lambda x.\text{leave}(x) : g_\sigma \multimap h_\sigma}{\text{leave(gonzo)} : h_\sigma} \qquad \lambda \mathcal{P}.\text{seem}(\mathcal{P}) : h_\sigma \multimap f_\sigma}{\text{seem(leave(gonzo))} : f_\sigma}$$

This proof is substantially different from the one in Figure 1.1 on page 15. The raised subject first combines with its predicate (i.e. the predicate that selects for it), in this case *leave*, to give the meaning of the XCOMP, which is a proposition. Then, the XCOMP combines with its predicate, the raising verb. The result is that the raising verb is a one-place predicate taking a proposition as its argument.

Furthermore, the fact that the raised subject plays no role in the semantics of the raising verb means that a raising sentence like (2) is treated as synonymous by this analysis to the corresponding sentence with an expletive subject and a finite propositional complement.[10] It is simple to show this. Consider the following sentence.

(27) It seemed that Gonzo left.

This yields an f-structure in many respects similar to (16).

(28)
$$f\begin{bmatrix} \text{PRED} & \text{`seem}\langle(\uparrow \text{COMP})\rangle(\uparrow \text{SUBJ})\text{'} \\ \text{SUBJ} & i\begin{bmatrix} \text{EXPL} & + \\ \text{FORM} & \text{IT} \end{bmatrix} \\ \text{COMP} & h\begin{bmatrix} \text{PRED} & \text{`leave}\langle(\text{SUBJ})\rangle\text{'} \\ \text{SUBJ} & g\begin{bmatrix} \text{PRED} & \text{`Gonzo'} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

There are a two crucial differences, though. First, the matrix subject is an expletive, and has no PRED. Second, the lower subject is only the subject of the COMP[11] and is not structure-shared with the matrix subject.

Most importantly, the expletive subject does not contribute to the semantics of the clause and therefore does not provide a Glue premise. As a result, we use the same Glue premises from (25) (modulo the

[10] The synonymy may break down when tense is taken into consideration, but I have left this aside here.

[11] LFG uses the grammatical function XCOMP for open complements that need to have a grammatical function specified from elsewhere, as we have seen thus far, and COMP for a complete complement which is missing no arguments.

xcomp/comp distinction in f-structure) to construct the same proof, (26). Thus, (2) is synonymous with (27), as they both have the meaning *seem(leave(gonzo))*. This is a desirable result, given that the meaning language is an intensional predicate calculus without events or tenses.[12]

6.3 Summary

In this section I have shown that it is possible to give an empirically motivated semantics for both equi and raising using Glue semantics. Structure-sharing is not necessarily at odds with resource-sensitivity, and in fact these constraints that come from the formal architecture result in an elegant analysis that provides the empirically motivated property denotation for the controlled complement. At the same time, the treatment of raising yields the required propositional denotation for the sentential complement of the raising verb.

7 Conclusion

I have described two main results in this paper. First, it is possible to give a Glue semantics analysis of equi verbs such that there is no need for the controlled verb to consume its subject resource. Thus, although there is functional identity in the syntax, which means that there is only one resource contributed by the structure-shared subject, this does not cause a problem for the resource-sensitive Glue semantics. Second, this approach to the semantics of control allows us to maintain that the controlled complement denotes a property, thus accounting for the robust inference pattern in (9), which was discussed by Chierchia (1984).

In related work (Asudeh, 2000), I demonstrate the empirical coverage of this analysis further. The phenomena I address are: 1) iterated raising and control and combinations thereof, which result in multiply-shared f-structures; 2) reflexive binding in the controlled complement, which has been problematic for previous versions of the property theory of control; 3) anaphoric control in equi, as demonstrated in languages such as Serbo-Croatian (Zec, 1987) and Icelandic (Andrews, 1982);[13] 4) the de dicto/de re differences between the embedded subjects of equi and raising complements. In all four cases, I show that the Glue

[12] Notice that (2) has an infinitival clause embedded in a matrix past tense clause, while (27) has a past tense clause embedded under a matrix clause that is also in the past tense. If events and tense are taken into account, the synonymy between the two sentences may break down, depending on the particular analysis of events and sequence of tenses assumed.

[13] See footnote 4 above.

semantics approach and LFG's parallel projection architecture provide elegant solutions to long-standing problems in the semantics of equi and its relation to raising.

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